8 Hydrologic Analysis

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- *Emerging techniques for modeling LID*

Several methods of hydrologic analysis have been developed for modeling low impact development (LID) designs. Single event models have been most commonly used and a national method based on the Soil Conservation Service TR-55 model is available through the U.S. Environmental Protection Agency (EPA publication 841-B-00-02).

Single event methods, however, have limitations for modeling western Washington stormwater facilities. For example, a single event method does not account for the effects of storms that occur just before or after a single storm event and the associated antecedent soil moisture conditions.

The Washington Department of Ecology (Ecology) recommends that local jurisdictions in western Washington adopt the Western Washington Hydrologic Model (WWHM), an HSPF (Hydrologic Simulation Program-Fortran)-based model. Ecology recommends WWHM for several reasons, including:

- WWHM uses long-term and local precipitation data that accounts for various rainfall regimes in western Washington.
- The modeling methodology better accounts for previous storm events and antecedent soil moisture conditions.
- The various land categories describing hydrologic factors that influence runoff characteristics are calibrated using data collected by the U.S. Geological Service (USGS) in western Washington watersheds.

While WWHM provides advantages for designing stormwater facilities in western Washington, there are challenges for applying the model to low impact development designs. LID utilizes multiple, small-scale stormwater controls that are distributed yet often connected throughout the development. Flows are directed to these facilities from small contributing areas and stormwater that is not infiltrated, evaporated or transpired in one facility is directed to the next. This presents two challenges when using WWHM in this design setting:

- WWHM has limited routing capability, and while the model has been expanded to allow routing through multiple facilities, the procedure remains time and computing intensive for the large number of facilities in LID projects (AHBL, 2004).
- Pervious land category values (PERLNDs) for WWHM are based on local USGS studies. Pervious surfaces and soil treatments in a low impact development include compost amended soil, bioretention areas with engineered soil mixes, and pervious pavement with aggregate storage. The LID pervious surface treatments, or land categories, will likely behave differently than the calibrated PERLNDs in the WWHM. Pilot projects and associated monitoring are needed to provide necessary data to help further calibrate the WWHM to these new strategies.

8.1 Emerging Modeling Techniques

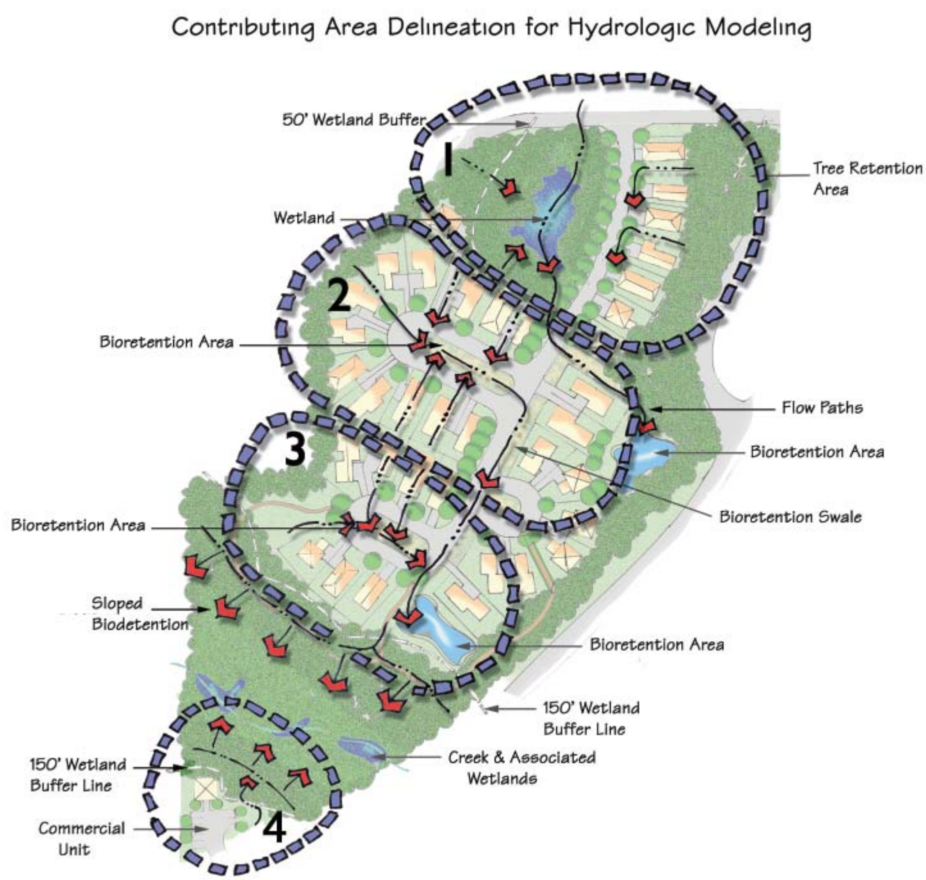
8.1.1 Micro-Basin Characterization

AHBL Engineers in Tacoma developed a micro-basin characterization technique to compensate for the routing limitations of the WWHM:

- The project is divided into small basins according to topography, lot, and street layout and LID stormwater facility configuration (see Figure 8.1 for a conceptual representation of the basin delineation).
- The contributing area is based on the bioretention cell or segment of bioretention swale and the area that contributes surface flows to that cell or swale.
- Areas are derived from design plans for roof areas, driveways, landscaping, and undisturbed areas for each basin.
- Storm flows from the basin are then routed through the bioretention cell or portion of the bioretention swale.
- An equivalent basin is generated that has characteristics that match the outflow from the bioretention cell or segment of swale.
- After all individual basins are defined, they are combined and routed to the next facility or used for the final development runoff.
  (AHBL, 2004)

Figure 8.1 Basin delineation.

Graphic by AHBL Engineering



8.1.2 WWHM and LID Flow Control Credits

See Chapter 7: Washington Department of Ecology Low Impact Development Design and Flow Modeling Guidance for flow control credits when using bioretention, green roofs, rooftop rainwater harvesting, permeable paving, minimal excavation foundations, and dispersion techniques.

8.1.3 An Approach for Modeling Bioretention Swales and Compost Amended Soils

Herrera Environmental Consultants performed hydrologic modeling to evaluate the expected performance of a Natural Drainage System (NDS) for the High Point Revitalization Project in Seattle. The primary objectives of the hydrologic modeling were to evaluate compliance with overall stormwater performance goals for the site, cost effectiveness, and design optimization for the NDS.

Key elements of the proposed NDS include bioretention and conveyance swales that are distributed throughout the site within the public rights-of-way, disconnection of rooftop runoff from the storm drain system, and extensive use of compost amended soils.

Existing models are not ideally suited for examining the microscopic surface and subsurface dynamics of bioretention swales and their complex interaction with other stormwater management practices (e.g., rooftop dispersion and compost amended soil). Accordingly, Herrera developed new modeling techniques to more accurately assess the detailed performance of the bioretention swales at the city block-scale, as well as the cumulative performance of all elements of the NDS strategy for the entire High Point site.

The bioretention swales for High Point are complex in design, with multiple distinct layers governing their flow control capacity. These layers consist of a grass-lined or vegetated swale surface, a 6-foot thick engineered soil layer, and a 6-foot thick gravel under-drain layer. The swale is designed to retain stormwater at the surface long enough to allow infiltration into the underlying engineered soil layer. The engineered soil provides the primary mechanism for flow control. Stormwater is retained for longer periods of time and is exfiltrated through the sides of the swale to surrounding native soils. Moisture that does not exfiltrate within the engineered soil layer drains to the underlying gravel layer, which allows for additional exfiltration through the sides and bottom of the swale.

The bioretention swales were modeled in HSPF as a series of interconnected stage-storage-discharge relationships, or functional tables (FTABLEs). One FTABLE was used to represent each distinct layer of the swale. For the grass-lined or vegetated surface swale, FTABLE development was based on Manning's equation for open channels. The FTABLE for the engineered soil layer was of critical importance for predicting the overall performance of the bioretention swales, since this layer provides the primary flow control mechanism for the swales. This FTABLE was developed based on detailed modeling performed using MODRET software, which is a groundwater model capable of predicting dynamic surface water and groundwater interactions. The FTABLE for the under-drain layer was based on Darcy's Law for saturated flow through gravel. The FTABLEs for each layer were connected within HSPF, allowing for exfiltration to the native soils as well as one-way flow between layers (e.g., from the surface swale to the engineered soil layer, or from the engineered soil to the under-drain layer).

For the overall site-scale modeling, compost amended soils were modeled in HSPF as PERLNDs with lateral inflow from disconnected rooftop downspouts. Model parameters for these PERLNDs were modified from the USGS regional calibration parameters for till soils with grass cover in order to represent the enhanced infiltration offered by amended soils (Dinicola, 1990). The parameter adjustments were based on an HSPF calibration study by Kurtz (1996), which used data obtained from experimental plots at the University of Washington's Center for Urban Horticulture.

Runoff from rooftops was modeled as lateral inflow to lawns, or compost amended soil, down gradient from the downspouts. Lateral inflow is analogous to additional rainfall input to these receiving areas. For purposes of reflecting reasonable hydraulic loading rates, the areas receiving rooftop runoff were estimated using the following approach:

- Each building structure was assumed to have four downspouts contributing to the adjacent pervious area.
- Downspout discharge was assumed to spread at a 45 degree angle and sheet flow a distance of 10 feet onto the adjacent pervious area.

This modeling approach was successful for meeting the objectives of the study. Long-term monitoring of the site is scheduled to begin Fall 2004. Results from the monitoring study will be used to verify the modeling approach.

8.1.4 CH2M HILL LIFE™ Model

CH2M HILL developed the Low Impact Feasibility Evaluation (LIFE™) model specifically for evaluating the performance of various LID techniques. The LIFE™ model provides a continuous simulation of the runoff and infiltration from new or redeveloped areas, or from a watershed or sub-catchment with multiple land use categories utilizing the following inputs:

- Continuous rainfall data (typically in time increments of 1 hour or less) and evapotranspiration data (typically daily time increments) evaluated for time periods of one year or more.
- Site design parameters and land cover characteristics for each land category being modeled (e.g., road width, rooftop coverage, surface parking, etc.).
- Information on LID techniques that are applied for each land use type including:
  - Extent of source control application (e.g., percent of road and building lots with specific source controls).
  - Source control design parameters (e.g., area and depth of infiltration facilities, soil depth for green roofs, volume of rainwater harvesting cisterns, etc.).
- Soils information including:
  - Surface parameters (e.g., maximum water content, rooting depth of vegetation).
  - Subsurface parameters (e.g., saturated hydraulic conductivity).

The model provides total runoff volume, flow duration curves, and flow hydrographs as outputs to assess the performance of LID designs (CH2M HILL, 2004).

The LIFE™ model has not had extensive calibration. Pilot projects and associated monitoring will provide necessary data to help further calibrate the model to specific LID practices and expected overall performance of projects using multiple LID techniques.